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Attorney Docket HAG 111

PATENT APPLICATION TRANSMITTAL LETTER

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Transmitted herewith for filing is the patent application of Tsutomu SHOKI

for X-RAY MASK BLANK AND X-RAY MASK

Enclosed are:
[XX] 3 sheets of drawing(s)
[XX] Formal
[ ] Informal

[XX] An Assignment of the invention to: Hoya Corporation

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[XX] Information Disclosure Sheet & References

[ ] Appointment of Associate Attorneys

[ ] Priority Document(s)
No: ____________ No: ____________
Date: ____________ Date: ____________

[ ] Preliminary Amendment A

[XX] Other Assignment Cover Sheet

Date: March 31, 1998

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SPECIFICATION

TITLE OF THE INVENTION

X-RAY MASK BLANK AND X-RAY MASK

REFERENCE TO RELATED APPLICATION

This application claims the priority right under 35 U.S.C 119, of Japanese Patent Application No. Hei 09-80762 filed on March 31, 1997, the entire disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates to an x-ray mask for use in an x-ray lithography method and an x-ray mask blank which is a material of the x-ray mask.

2. Description of the Related Art:

In a semiconductor industry, as a technique for forming an integrated circuit constituted of a fine pattern on a silicon substrate or the like, a photolithography method for transferring the fine pattern by the use of a visible light and an ultraviolet light as an exposing electromagnetic wave is well known. However, a recent advance in a semiconductor technique greatly promotes a high integration of a semiconductor device such as VLSI, and this results in a requirement for the technique for transferring the

fine pattern with high accuracy beyond a transfer limit (a principled limit due to a wavelength) of the visible light and the ultraviolet light for use in the conventional photolithography method. In order to transfer such a fine pattern, an x-ray lithography method using an x-ray whose wavelength is shorter than the wavelength of the visible light and the ultraviolet light is attempted.

Fig. 1 is a cross sectional view showing a structure of an x-ray mask for use in the x-ray lithography. Fig. 2 is a cross sectional view showing the structure of an example of an x-ray mask blank as an intermediate product obtained in an intermediate process during manufacturing the x-ray mask.

As shown in Fig. 1, an x-ray mask 1 comprises an x-ray membrane 12 for transmitting the x-ray and an x-ray absorbing film pattern 13a formed on the x-ray membrane 12. The x-ray membrane 12 is supported by a silicon frame body 11a which is formed by removing the other portion so that the periphery alone of the silicon substrate may remain. When this x-ray mask 1 is manufactured, the x-ray mask blank to be the intermediate product is manufactured in the intermediate process. This x-ray mask blank is further processed, so that the x-ray mask is obtained. In this industry, although, of course, the x-ray mask which is a finished product is to be dealt in, the x-ray mask blank which is the intermediate product is also often to be independently dealt in.

As shown in Fig. 2, an x-ray mask blank 2 comprises the x-ray membrane 12 formed on a silicon substrate 11 and an x-ray absorbing film 13 formed on the x-ray membrane.

Silicon nitride, silicon carbide, diamond or the like is generally used as the x-ray membrane 12. An amorphous material including tantalum (Ta) having an excellent resistance to x-ray radiation is often used as the x-ray absorbing film 13.

For the process of manufacturing the x-ray mask 1 from the x-ray mask blank 2, for example, the following method is used. That is, a resist film on which a desired pattern is formed is arranged on the x-ray mask blank 2 shown in Fig. 2. This pattern is then used as a mask so as to perform a dry etching, so that the x-ray absorbing film pattern is formed. After that, a center area formed on a rear surface and to be a window area of the x-ray membrane 12 is removed by a reactive ion etching (RIE) using 4-fluorocarbon (CF_4) as etching gas. The remaining film (12a: see Fig. 1) is then used as the mask so as to etch the silicon substrate 11 by an etching liquid constituted of a mixed liquid of fluoric acid and nitric acid, whereby the x-ray mask 1 (see Fig. 1) is obtained. In this case, an electron beam (EB) resist is generally used as the resist, and the pattern is formed by means of an EB lithography.

For the x-ray membrane 12, a high transmittance to the x-ray, a high Youngís modulus of elasticity, a proper tensile stress, a resistance to x-ray radiation, the high transmittance

within a visible light range and the like are required. The characteristics will be described below. The transmittance to the x-ray is required during an exposure. The higher the transmittance is, the shorter a time required for the exposure can become. This is effective for improving throughput. The Youngis modulus of elasticity has an influence on a strength of the film and a deformation of an absorber pattern. The higher the Youngis modulus of elasticity is, the higher the film strength becomes. This is effective for suppressing misalignment. The proper tensile stress is needed in order that the film is self-supported. Since the x-ray membrane is irradiated with the x-ray during the exposure, it is necessary to cause no damage due to this x-ray radiation, and thus the resistance to x-ray radiation is required. Since an alignment of the mask attached to an x-ray stepper and a wafer is accomplished by the use of a light source within the visible light range, the high transmittance to an alignment light source (the visible light) is needed in order to achieve a highly accurate alignment. Furthermore, a film surface is required to be smooth. A surface smoothness is needed for a highly accurate pattern formation on the absorber.

In order to satisfy these requirements, various materials and manufacturing methods have been studied. Since it is confirmed that the silicon carbide causes no damage due to the x-ray in the silicon nitride, the silicon carbide (SiC) and the diamond which have been heretofore used as the x-ray membrane, it

may safely be said that the silicon carbide is the most promising material. However, since the SiC film for the general use has a polycrystalline structure, the SiC film has the film surface which is rougher than 6 nm (Ra: a center-line average roughness) due to a crystalline structure. For smoothing of the surface of this SiC film, an etch back method and a mechanical polishing method are carried out after the film formation. The etch back method is the technique in which the rough SiC film is coated with the resist and the thus obtained smooth resist surface is transferred onto the SiC film by the dry etching. The mechanical polishing is the method in which a hard grain such as the diamond and alumina is used as an abrasive material so as to physically grind an unevenness on the surface of the SiC film. For example, according to Japanese Patent Publication No. 7-75219, the surface roughness of 20 nm or less is obtained by the etch back and the mechanical polishing. Although a definition of the surface roughness is not clear in this publication, this roughness is expected to be a maximum height (Rmax) and corresponds to about 2 nm or less in terms of Ra.

Recently, due to the advance in the photolithography technique, an introduction of the x-ray lithography has been performed later. At present, the introduction from a generation of 1G bit-DRAM (design rule: 0.18 μm) is anticipated. Even if the x-ray lithography is introduced from 1G, the x-ray lithography is characterized by that it can be used through a plurality of

generations up to 4G, 16G and 64G. Assuming that the x-ray lithography is used for 64G, a position precision required for the x-ray mask becomes severer, and thus the position precision is required to be as high as 10 nm. The inventor has already found that, in order to suppress to such a position precision, it is effective to equalize an internal stress in an area in which a mask pattern is formed on the x-ray absorbing film (Japanese Patent Application No. 8-233402). As a result of a further study, the inventor has found that the surface roughness of the x-ray membrane has a sensitive influence on a stress distribution of the x-ray absorbing film formed on the x-ray membrane.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an x-ray mask blank in which a stress distribution of an x-ray absorbing film is suppressed and an x-ray mask capable of a highly precise pattern transfer.

In accordance with the first aspect of the present invention, there is provided an x-ray mask blank having at least an x-ray membrane on a substrate, wherein the x-ray membrane has a surface condition satisfying the following expression (1):

$$(Ra_{max}-Ra_{min})/(Ra_{max}+Ra_{min}) \leqq 0.15 \qquad (1)$$

where Ra_{max} denotes a maximum value of Ra of a surface roughness (Ra: center-line average roughness) on a plurality of

points within a predetermined area on the x-ray membrane, and Ra_{min} denotes a minimum value of Ra of the surface roughness (Ra: center-line average roughness) on a plurality of points within a predetermined area on the x-ray membrane.

In accordance with the second aspect of the present invention, there is provided an x-ray mask blank according to the first aspect, wherein an average of the surface roughness (Ra: center-line average roughness) on a plurality of points within a predetermined area on the x-ray membrane is 1.0 nm or less.

In accordance with the third aspect of the present invention, there is provided an x-ray mask blank according to the first or second aspect, wherein the surface of the x-ray membrane is a generally uniformly polished surface.

In accordance with the fourth aspect of the present invention, there is provided an x-ray mask blank according to any one of the first through third aspects, wherein the x-ray membrane comprises a silicon carbide film.

In accordance with the fifth aspect of the present invention, there is provided an x-ray mask having an x-ray absorbing film pattern on an x-ray membrane supported by a frame body, wherein the x-ray mask is manufactured by the use of the x-ray mask blank according to any one of the first through fourth aspects.

The inventor has studied the surface roughness of the x-ray membrane and the stress distribution of the x-ray absorbing film.

As a result, it is found that the distribution of the surface roughness of the x-ray membrane would cause the stress distribution of the absorbing film and thus a pattern position precision is deteriorated. The condition of the distribution of the surface roughness can be represented by the value of the left side of the expression (1). Now, assuming that the value of the left side of the expression (1) is defined as the value of the distribution of the surface roughness, if the value of the distribution of the surface roughness of the x-ray membrane exceeds 0.15 (15%), the stress distribution of the x-ray absorbing film is increased, which may deteriorate the pattern position precision. Preferably, the value of the distribution of the surface roughness of the x-ray membrane is 0.15 or less. More preferably, the value is 0.1 or less.

Since it is important for the x-ray absorbing film to control the stress distribution within the area in which a mask pattern is formed, it is preferable to similarly control the distribution of the surface roughness of the x-ray membrane within the area in which the mask pattern is formed. Furthermore, the average of the surface roughness (Ra: center-line average roughness) on a plurality of points within a predetermined area on the x-ray membrane is 1.0 nm or less, whereby it is possible to suppress the distribution of the surface roughness of the x-ray membrane to some extent.

A silicon substrate or the like is herein used as the

substrate. SiC, SiN, diamond or the like is used as the x-ray membrane. More specifically, preferably, SiC is used in view of a resistance to x-ray radiation.

Moreover, in order to suppress variation in the surface roughness of the x-ray membrane, it is effective to uniformly polish the substrate having the x-ray membrane. For this purpose, the substrate having the x-ray membrane is affixed to a substrate fixing jig, and a load to polishing means such as an abrasive cloth is applied to the substrate fixing jig so as to polish the substrate, whereby the substrate can be uniformly polished. Preferably, a method of affixing the substrate having the x-ray membrane to the substrate fixing jig is the method of affixing the substrate to an SUS jig through water (a water affixing method). That is, the method of affixing the substrate to the substrate fixing jig by the use of a wax, an adhesive tape or the like is not preferable, because the relatively thin substrate such as the x-ray mask blank is prone to a deformation during being affixed and thus the variation in polishing is caused when the substrate is polished. On the other hand, if the substrate is affixed to the substrate fixing jig by the use of the water affixing method, the deformation of the substrate can be avoided when the substrate is affixed, and thus the uniform polishing is possible. More specifically, when SiC is used as the x-ray membrane, it is preferable to apply the load of about 50-400 g/cm^2. Since SiC is the hard film, it is preferable that the diamond is

used as an abrasive material. It should be noted that a method as described below is used in order to prevent a scratch from being made on the surface. That is, the surface is polished by the use of the diamond whose average particle diameter is as relatively small as about 0.05-0.3 μm or the diamond whose average particle diameter is larger than the former (about 0.3-0.6μm), and then the surface is polished by the use of colloidal silica. Moreover, when the colloidal silica is used without the use of the diamond, hydrogen peroxide is contained in the colloidal silica, whereby it is possible to obtain the surface which is flat and is not scratched.

The x-ray mask blank of the present invention may be the one in which the film constituted of an etching stop layer, an adhesive layer, a reflection preventing layer and a conductive layer is disposed between the x-ray membrane and the x-ray absorbing film. Alternatively, the x-ray mask blank may be also the one in which a mask layer, a protective layer and a conductive layer are disposed on the x-ray absorbing film.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross sectional view for describing a structure of an x-ray mask;

Fig. 2 is a cross sectional view for describing the structure of an x-ray mask blank;

Fig. 3 is an illustration of a method of manufacturing the

x-ray mask according to embodiments of the present invention; and

Fig. 4 is a table generally showing a distribution value of a surface roughness of an x-ray membrane, an average of the surface roughness of the x-ray membrane, a stress distribution of an x-ray absorbing film and a position precision of an x-ray absorbing film pattern of the embodiments and a comparison example.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

An x-ray mask blank and an x-ray mask of embodiments will be described with reference to Fig. 3.

[Embodiment 1]

[Formation of x-ray membrane]

In the first place, a silicon carbide film is formed as an x-ray membrane 12 on both the surfaces of a silicon substrate 11. The silicon substrate of 4 in. ϕ in size, of 2 mm in thickness and of a crystalline orientation of (100) is used as the silicon substrate 11. The silicon carbide film as the x-ray membrane is also formed to 2.1 μm in thickness by a CVD process by the use of dichlorosilane and acetylene. Next, the surface of the x-ray membrane 12 is smoothed by a mechanical polishing. The mechanical polishing is performed in the following manner. First, the rear surface of the substrate on which the x-ray membrane 12 is formed is affixed to a stainless (SUS) jig by a water affixing method, and the film surface is brought into contact with a solidifying

polymer type soft abrasive cloth in which a diamond particle of an average particle diameter of 1/8μm (0.05-0.35 μm in diameter: Nihon Engis) is dispersed. Then, a load of 200 g/cm^2 is applied to the jig while the jig is rotated at 60 rpm, whereby the surface is polished for five minutes.

A surface roughness (Ra) on 100 points within a range of 30 × 30 mm at the center of the substrate on the thus obtained surface is measured by an atomic force microscope, and a value (a distribution value of the surface roughness) of the left side of an expression (1) is determined from a maximum value of Ra and a minimum value of Ra. The resultant value is 0.05, and the average of the surface roughness is 0.35 nm. At this time, a scratch on the surface is 0.2 μm or less.

[Formation of x-ray absorbing film]

Next, as shown in Fig. 3(B), an x-ray absorbing film 13 of tantalum and boron is formed to 0.5μm in thickness on the x-ray membrane 12 by a DC magnetron sputtering process. A sintered body containing tantalum and boron in an atomicity ratio (Ta/B) of 8 to 2 is used as a sputter target. Sputter gas is Xe, an RF power density is set at 6.5 W/cm^2 and a sputter gas pressure is set at 0.35 Pa. Next, this substrate is annealed at 250℃ for two hours in a nitrogen atmosphere so as to thereby obtain the x-ray absorbing film 13 of a low stress of 10 MPa or less. At this time, a stress of the x-ray absorbing film is measured by a highly

precise stress measuring unit (WS-5000: NTT Advance Technology) within the same range as the above-described range in which the surface roughness of the x-ray membrane is measured. As a result, the stress is 0±4 MPa.

[Formation of etching mask layer]

Next, as shown in Fig. 3(C), a chromium film containing chromium carbide is formed as an etching mask layer 14 on the x-ray absorbing film 13 by an RF magnetron sputtering process so that it may be 0.05 μm in thickness. Cr is used as the sputter target, the sputter gas is the gas in which 7% of methane is mixed into Ar, the RF power density is set at 6.5 W/cm^2 and the sputter gas pressure is set at 1.2 Pa, thereby obtaining the etching mask layer of the low stress of 100 MPa or less.

A product obtained in this step is also dealt as one type of the x-ray mask blank.

[Formation of x-ray absorbing film pattern and Formation of frame body]

A resist film on which a desired pattern is formed is arranged on an x-ray mask blank 2. This pattern is used as the mask so as to perform a dry etching, whereby the x-ray absorbing film pattern is formed. Then, a center area formed on the rear surface and to be a window area of the x-ray membrane 12 is removed by a reactive ion etching (RIE) by the use of CF_4 as etching gas. A remaining film 12a is then used as the mask so as to etch the silicon substrate 11 by an etching liquid constituted

of a mixed liquid of fluoric acid and nitric acid, whereby an x-ray silicon frame body 11a is formed and the x-ray mask is thus obtained. In this case, an electron beam (EB) resist is generally used as the resist, and the pattern is formed by means of an EB lithography.

A misalignment of the x-ray absorbing film pattern (an actual shift of the pattern with respect to a design pattern) of the x-ray mask manufactured by this embodiment is evaluated by a coordinate measuring device. As a result, a position precision is 18 nm and sufficient.

[Embodiment 2]

[Formation of x-ray membrane]

In the first place, the silicon carbide film is formed as the x-ray membrane 12 on both the surfaces of the silicon substrate 11. The silicon substrate of 4 in. ϕ in size, of 2 mm in thickness and of the crystalline orientation of (100) is used as the silicon substrate 11. The silicon carbide film as the x-ray membrane is also formed to 2.1 μm in thickness by the CVD process by the use of dichlorosilane and acetylene. Next, the surface of the x-ray membrane 12 is smoothed by the mechanical polishing. The mechanical polishing is performed in the following manner. First, the rear surface of the substrate on which the x-ray membrane 12 is formed is affixed to the stainless (SUS) jig, and the film surface is brought into contact with the solidifying polymer type soft abrasive cloth in which the diamond particle of

the average particle diameter of 1/4 μm (0.1-0.6 μm in diameter: Nihon Engis) is dispersed. Then, the load of 200 g/cm^2 is applied to the jig while the jig is rotated at 60 rpm, whereby the surface is polished for five minutes, so that the surface of the surface roughness of 1 nm or less in terms of Ra is obtained. However, the scratch of 0.2 μm or more is on the surface of the thus obtained film. Therefore, moreover, the rear surface of the substrate is fixed to the SUS jig, and the substrate is brought into contact with a suede type (nonwoven fabric type) abrasive cloth in which colloidal silica (its particle diameter: 60-80 nm) is dispersed. Then, the load of 180 g/cm^2 is applied to the jig while the jig is rotated at 60 rpm, whereby the surface is polished for five minutes, so that the scratch is reduced to 0.2 μm or less on the surface. When the distribution of the surface roughness of the thus obtained x-ray membrane is determined in the same manner as the first embodiment, the distribution is 0.08 and the average of the surface roughness is 0.70 nm. The thus obtained product is also dealt as one type of the x-ray mask blank.

[Formation of x-ray absorbing film]

Next, as shown in Fig. 3(B), the x-ray absorbing film 13 of tantalum and boron is formed to 0.5 μm in thickness on the x-ray membrane 12 by the DC magnetron sputtering process. The sintered body containing tantalum and boron in the atomicity ratio (Ta/B) of 8 to 2 is used as the sputter target. The sputter gas is Xe,

the RF power density is set at 6.5 W/cm^2 and the sputter gas pressure is set at 0.35 Pa. Next, this substrate is annealed at 250℃ for two hours in the nitrogen atmosphere so as to thereby obtain the x-ray absorbing film 13 of the low stress of 10 MPa or less. When the stress distribution on the surface of this film is determined in the same manner as described above, the stress distribution is 0±5 MPa. The product obtained in this step is also dealt as one type of the x-ray mask blank.

[Formation of etching mask layer]

Next, as shown in Fig. 3(C), the chromium film containing chromium carbide is formed as the etching mask layer 14 on the x-ray absorbing film 13 by the RF magnetron sputtering process so that it may be 0.05 μm in thickness. Cr is used as the sputter target, the sputter gas is the gas in which 7% of methane is mixed into Ar, the RF power density is set at 6.5 W/cm^2 and the sputter gas pressure is set at 1.2 Pa, thereby obtaining the etching mask layer of the low stress of 100 MPa or less. The product obtained in this step is also dealt as one type of the x-ray mask blank.

[Formation of x-ray absorbing film pattern and Formation of frame body]

The resist film on which a desired pattern is formed is arranged on the x-ray mask blank 2. This pattern is used as the mask so as to perform the dry etching, whereby the x-ray absorbing film pattern is formed. Then, the center area formed on

the rear surface and to be the window area of the x-ray membrane 12 is removed by the reactive ion etching (RIE) by the use of 4-carbonfluoride (CF_4) as the etching gas. The remaining film 12a is then used as the mask so as to etch the silicon substrate 11 by the etching liquid constituted of the mixed liquid of fluoric acid and nitric acid, whereby the x-ray silicon frame body 11a is formed and the x-ray mask is thus obtained (see Fig. 3(D)). In this case, the electron beam (EB) resist is generally used as the resist, and the pattern is formed by means of the EB lithography.

The misalignment of the x-ray absorbing film pattern of the x-ray mask manufactured by this embodiment is evaluated by the coordinate measuring device. As a result, the position precision is 15 nm and sufficient.

[Embodiment 3]

This embodiment is the same as the first and second embodiments except that the following mechanochemical polishing is performed as the step of polishing the silicon carbide film which is the x-ray membrane 12 in the step of forming the x-ray membrane 12 in the first and second embodiments.

The mechanochemical polishing of this embodiment is carried out in the following manner. That is, the substrate is brought into contact with the solidifying polymer type abrasive cloth in which the colloidal silica (its particle diameter: 60-80 nm) is dispersed, and then the load of 180 g/cm^2 is applied to the substrate while the substrate is rotated at 60 rpm, whereby the

surface is polished for ten minutes. At this time, 30% of H_2O_2 is added into colloidal slurry, whereby pH of solvent medium is changed into weak alkali (8.5). In such a manner, a catalytic action gets active, and thus a polishing speed can be increased and the surface can be smoothed.

In this embodiment, after the polishing of the x-ray membrane is completed, the distribution of the surface roughness of the x-ray membrane is determined in the same manner as the first embodiment. As a result, the distribution is 0.12, and the average of the surface roughness is 0.85 nm.

After forming the x-ray absorbing film, the stress distribution of the x-ray absorbing film is determined in the same manner as the first embodiment. As a result, the stress distribution is 0 ± 6 MPa.

Furthermore, the misalignment of the x-ray absorbing film pattern of the x-ray mask manufactured by this embodiment is evaluated by the coordinate measuring device. As a result, the position precision is 20 nm and satisfies the required position precision.

[Comparison example]

This comparison example is the same as the first embodiment except the method of fixing the rear surface of the substrate on which the x-ray membrane 12 is formed to the stainless (SUS) jig in the step of polishing the x-ray membrane 12 in the above-mentioned first embodiment. That is, unlike the first embodiment

(the water affixing method is used in the first embodiment), the rear surface is fixed by the use of a wax in the comparison example.

In this comparison example, after the polishing of the x-ray membrane is completed, the distribution of the surface roughness of the x-ray membrane is determined in the same manner as the first embodiment. As a result, the distribution is 0.25, and the average of the surface roughness is 0.43 nm.

After forming the x-ray absorbing film, the stress distribution of the x-ray absorbing film is determined in the same manner as the first embodiment. As a result, the stress distribution is 0±15 MPa.

Furthermore, the misalignment of the x-ray absorbing film pattern of the x-ray mask manufactured by this embodiment is evaluated by the coordinate measuring device. As a result, the position precision is 35 nm and cannot satisfy the required position precision.

Fig. 4 is a table generally showing the distribution value of the surface roughness of the x-ray membrane, the average of the surface roughness of the x-ray membrane, the stress distribution of the x-ray absorbing film and the position precision of the x-ray absorbing film pattern of the above embodiments and the comparison example. Although a compound of Ta and B (Ta/B=8/2) is used as the x-ray absorbing film in the above-mentioned embodiments, this may be replaced by a metal Ta,

an amorphous material containing Ta and tantalum boride having a composition other than Ta_4B, for example.

Additionally, a structure of the x-ray mask blank is not only the structure of the embodiments but also the so-called membraned structure in which the x-ray membrane is formed on the substrate and the center is then removed from the rear surface of the substrate so as to form the frame body whereby the x-ray membrane is laminated on this frame body. That is, it may safely be said that all the intermediate products in the step of manufacturing the x-ray mask are the x-ray mask blank.

Furthermore, an adhesive layer, a reflection preventing film or the like may be disposed between the x-ray membrane and the x-ray absorbing film. In this case, after forming these films, a defect is checked on the surface thereof.

WHAT IS CLAIMED IS :

1. An x-ray mask blank having at least an x-ray membrane on a substrate,

wherein said x-ray membrane has a surface condition satisfying the following expression (1):

$$(Ra_{max}-Ra_{min})/(Ra_{max}+Ra_{min}) \leqq 0.15 \qquad (1)$$

where Ra_{max} denotes a maximum value of Ra of a surface roughness (Ra: center-line average roughness) on a plurality of points within a predetermined area on said x-ray membrane, and

Ra_{min} denotes a minimum value of Ra of the surface roughness (Ra: center-line average roughness) on a plurality of points within a predetermined area on said x-ray membrane.

2. The x-ray mask blank according to claim 1, wherein an average of the surface roughness (Ra: center-line average roughness) on a plurality of points within a predetermined area on said x-ray membrane is 1.0 nm or less.

3. The x-ray mask blank according to claim 2, wherein the surface of said x-ray membrane is a generally uniformly polished surface.

4. The x-ray mask blank according to any one of claim 1, wherein said x-ray membrane comprises a silicon carbide film.

5. An x-ray mask having an x-ray absorbing film pattern on an x-ray membrane supported by a frame body, wherein said x-ray mask is manufactured by the use of said x-ray mask blank according to claim 1.

ABSTRACT OF THE DISCLOSURE

Disclosed are an x-ray mask blank and an x-ray mask wherein, assuming that Ra_{max} and Ra_{min} are defined as a maximum value of Ra and a minimum value of Ra of a surface roughness (Ra: center-line average roughness) on a plurality of points within a predetermined area on an x-ray membrane 12, respectively, the surface of the x-ray membrane 12 has a surface condition so that it may satisfy an expression: $(Ra_{max}-Ra_{min})/(Ra_{max}+Ra_{min}) \leqq 0.15$.

FIG. 1

1 X-RAY MASK

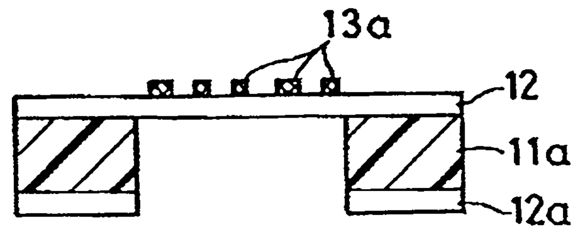

FIG. 2

2 X-RAY MASK BLANK

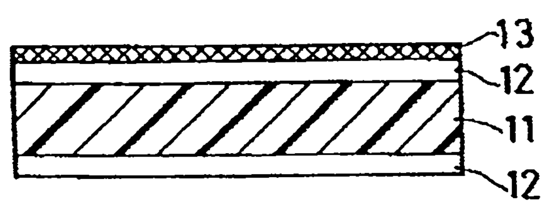

FIG.3A

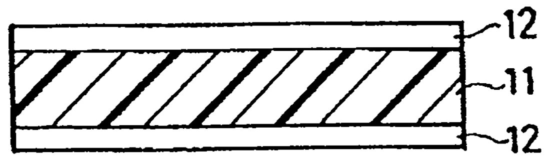

FIG.3B

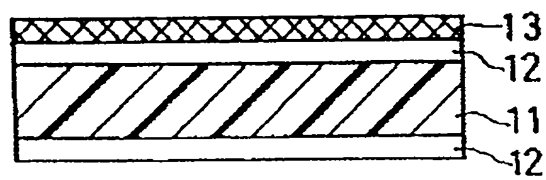

FIG.3C

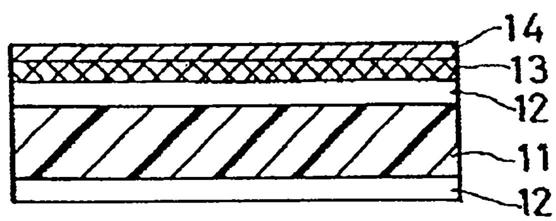

FIG.3D

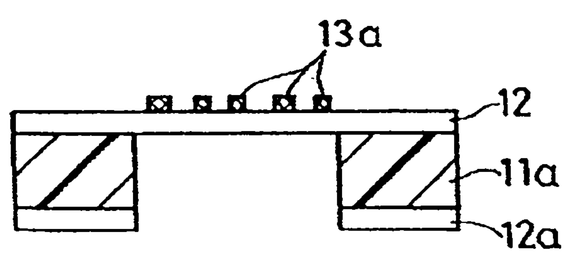

FIG. 4

	DISTRIBUTION VALUE OF SURFACE ROUGHNESS OF X-RAY MENBRANE	AVERAGE OF SURFACE ROUGHNESS OF X-RAY MENBRANE (nmRa)	STRESS DISTRIBUTION OF X-RAY ABSORBING FILM (×MPa)	POSITION PRECISION 3 σ (nm)
EMBODIMENT 1	0.05	0.35	0 ± 4	18
EMBODIMENT 2	0.08	0.70	0 ± 5	15
EMBODIMENT 3	0.12	0.85	0 ± 6	20
EMBODIMENT 4	0.25	0.43	0 ± 15	35

Attorney Docket No.________

DECLARATION AND POWER OF
ATTORNEY ORIGINAL PATENT APPLICATION

As a below named inventor, I hereby declare that:

Type of Application

This declaration is for the following type application:

__X__ Original
______ Design
______ National Stage of PCT
______ Divisional
______ Continuation
______ Continuation-in-Part (CIP)

Inventorship Identification

My residence, post office address and citizenship are as stated below next to my name, I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

X-RAY MASK BLANK AND X-RAY MASK

Specification Identification

The specification of which:

__X__ is attached hereto.

______ was filed on ____________________ as Application Serial No.____________________ and was amended on ____________________ (if applicable).

______ was described and claimed in PCT International Application No. ____________________ filed on ____________________ and as amended under PCT Article 19 on____________________ (if any).

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Acknowledgement of Review of Papers and Duty of Candor

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56, which provides:

(a) A patent by its very nature is affected with a public interest.The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclose information exists with respect to each pending claim until the claim is canceled or withdrawn from consideration or the application becomes abandoned. Information material to the patentability of a claim that is canceled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclose all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner described by § § 1.97 (b)–(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine; (1) prior art cited in search reports of a foreign patent office in a counterpart application, and (2) the closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made of record in the application, and

(1) it establishes, by itself or in combination with other

information, a prima facie case of unpatentability of a claim; or

(2) it refutes, or is inconsistent with, a position the applicant takes in:

(i) opposing an argument of unpatentability relied on by the Office, or

(ii) asserting an argument of patentability. A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

(1) each inventor named in the application;

(2) each attorney or agent who prepares or prosecutes the application; and

(3) every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.

(d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.

_______ In compliance with this duty there is attached an information disclosure statement, 37 CFR 1.97.

I do not know and do not believe that the invention was ever known or used in the United States of America before my or our invention thereof; I do not know and do not believe that the invention was ever patented or described in any printed publication in any country before my or our invention thereof or more than one year prior to this application; I do not know and do not believe that the invention was in public use or on sale in the United States of America more than one year prior to this application; and the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months prior to this application.

Priority Claim

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed.

_________ No such applications have been filed.

____X____ Such applications have been filed as follows.

Country	Application Number	Date of Filing (Month/Day/Year)	Priority Claimed	
			Yes	No
Japan	80762/1997	March 31, 1997	X	

Power of Attorney

As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

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Declaration

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Inventor's Signature Tsutomu Shoki Date Mar. 6, 1998